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THESIS

DEPLOYED VIRTUAL CONSULTING:
THE FUSION OF WEARABLE COMPUTING, COLLABORATIVE TECHNOLOGY, AUGMENTED REALITY AND INTELLIGENT AGENTS TO SUPPORT FLEET AVIATION MAINTENANCE

by

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13. ABSTRACT

This thesis analyzes the incorporation of modern technologies into the existing process of technical assistance rendered to deployed Naval aviation assets. The thesis focuses upon the effect and feasibility of fusing the technologies of wearable computing, collaborative virtual environments via the internet, intelligent agents, Control of Agent Based Systems, and augmented reality into a system that will enable deployed aviation maintainers to virtually consult with shore-based technical assets. The thesis demonstrates the viability of a network centric approach to maintenance by taking advantage of distributed assets and using cutting edge technology to "centralize" knowledge and allow unprecedented efficiencies to be realized in the maintenance arena in the areas of turn-around time and cost effectiveness.

The thesis documents the results of practical experimentation and outlines the necessary components of support from the existing command structure necessary to implement and sustain such a dramatic change to the maintenance environment.

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ABSTRACT

This thesis addresses the need of Naval Aviation Maintenance to streamline and more effectively manage the process of technical consultation aboard deployed aircraft carriers. The current process involves the physical transportation of an appropriate technician to the carrier to perform required maintenance and/or repairs. In light of the technology currently available this process becomes obviously obsolete, overly costly and needlessly time consuming.

By implementing wireless technology in combination with advanced software allowing the virtual collaboration of parties widely separated by geographical distance the Navy can establish a “virtual technical presence” onboard aircraft carriers wherever they may be in the world. This thesis will describe how the fusion of wearable computing, augmented reality, intelligent agents coupled with CoABS, and a modern collaborative software application can revolutionize Naval aviation maintenance as we know it. The technology is there – it only remains for the Navy to leverage it and take advantage of the significant returns that it will provide.

The implementation of this technology will allow maintainers onboard deployed aircraft carriers to consult in an augmented virtual environment with technical assets on the shore. These shore-based assets will then be able to “walk” deployed personnel through complicated repair procedures in a matter of minutes or hours as opposed to the previous need to wait for days for the technician to arrive.

This is a bold and innovative new concept that will allow commands at sea to increase their levels of combat readiness and allow them the ability to respond to ever changing mission needs. Turn around times for the repair of critical parts and assemblies will be reduced and readiness levels elevated. The ultimate goal of any command is mission accomplishment. This system will aid commands in achieving that all important goal.

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ACKNOWLEDGMENTS

The author would like to acknowledge the efforts of Ronald Pemberton of Groove Technologies for his assistance and knowledge regarding the proposed incorporation of Groove Collaborative software in the virtual consulting architecture.

The author would also like to thank Eugene for his many contributions to the experiments with the wearable computers, including the integration of streaming video software and various agents for network testing and development.

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I. INTRODUCTION

A. BACKGROUND AND PURPOSE

In today's ever more unpredictable world there is more need than ever for the Navy and the Department of Defense to have the ability to respond quickly and appropriately to crises as they occur. In order for the United States military to accomplish its mission it must have weapons systems that are ready and able to sustain combat operations abroad. This sustainability is a function of the proper and timely maintenance of such systems. The best weapons system in the world does the military that wields it no good if it is inoperable due to lack of, or improper, maintenance.

The advent of new computer and collaborative technologies has made it possible to streamline the maintenance process for assets that are deployed overseas and especially for those that are aboard afloat naval vessels. The aircraft carrier and its deployed air wing – the centerpiece of the U.S. Navy since World War II – has specialized and significant maintenance needs relative to its mission of projecting airpower abroad. The new technologies that this paper addresses represent an exciting new development in how the future Navy may conduct maintenance operations in order to sustain combat operations at sea.

These new technologies represent a significant departure from the existing methods of performing some types of maintenance and, thus, will require a significant adaptation by those who perform the maintenance as well as those ultimately responsible for the mission of the commands involved. The goal is to make these adaptations as painless and streamlined as possible, but inevitably there will be a certain amount of friction involved with the change regardless of the merit of the "new way".

The solution this thesis proposes is an entirely new and, for the Navy, somewhat novel approach to maintenance that will require significant commitment at all levels of the leadership structure. Based upon the experience of the author, extensive consultation with subject matter experts and knowledge gained in the course of study at the Naval Postgraduate School, the author feels that his approach could revolutionize the manner in which the Navy conducts maintenance operations and serve to act as a springboard for future applications based upon this technology and innovative approach.

This paper will attempt to address both the nature of the proposed changes and the manner in which personnel will need to adapt to support change and enable it to be a positive and productive endeavor.

The current method for providing technical assistance to deployed vessels has been necessitated largely by limitations in technology. It is currently necessary for a technician to physically relocate to the deployed asset to provide technical assistance. This is a cumbersome process that requires excessive amounts of both time and resources. A typical week-long visit by a technician to a deployed aircraft carrier can cost the Navy in excess of $6,000 dollars for salary, flight expense and incidentals. This is for a single instance. A typical deployment can easily require a dozen visits, or more, just for one department. This is a cost of over $70,000. Multiply this across eight or nine departments and we come up with a pretty large figure. Granted, not all departments will require in- depth technical assistance, but some, such as engineering and the Aircraft Intermediate Maintenance Department (AIMD), require a great deal on occasion.

A typical scenario for a technical assist for an AIMD could play out as follows: A hydraulic test bench in the Power Plants hydraulic shop is experiencing overheating and the maintenance technician cannot seem to resolve the problem. This bench is a critical piece of equipment as it tests the hydraulic actuators for aircraft control surfaces (elevators, ailerons, etc.). The maintenance technician will notify his chain of command that technical assistance is required to resolve the problem with the test bench and maintenance control will issue a technical assistance request through the Naval Technical Engineering Command (NATEC). A qualified technician will then be identified by NATEC to respond to the assist. The response time is normally around 48-72 hours for the technician to arrive on the ship assuming that he is immediately available. This time is essentially “dead time” for the test bench as it cannot be used.

The technician will have consulted with the maintainer regarding the symptoms that the bench is exhibiting and will attempt to bring the correct parts and tools with him at the time of response. However, it is sometimes necessary to subsequently order parts after arriving on scene. This adds to the down time of the bench and the time that the

technician must spend on the ship awaiting parts. The scenario is, of course, concluded when the repairs are successfully concluded and the technician is flown off the ship and back to NATEC.

It is quite obvious that this is a quite cumbersome and less-than-ideal process that can drastically benefit from the new technologies available. The figures below represent the current method of obtaining technical assistance and the proposed implementation of cutting edge technologies to transform and streamline the existing process.

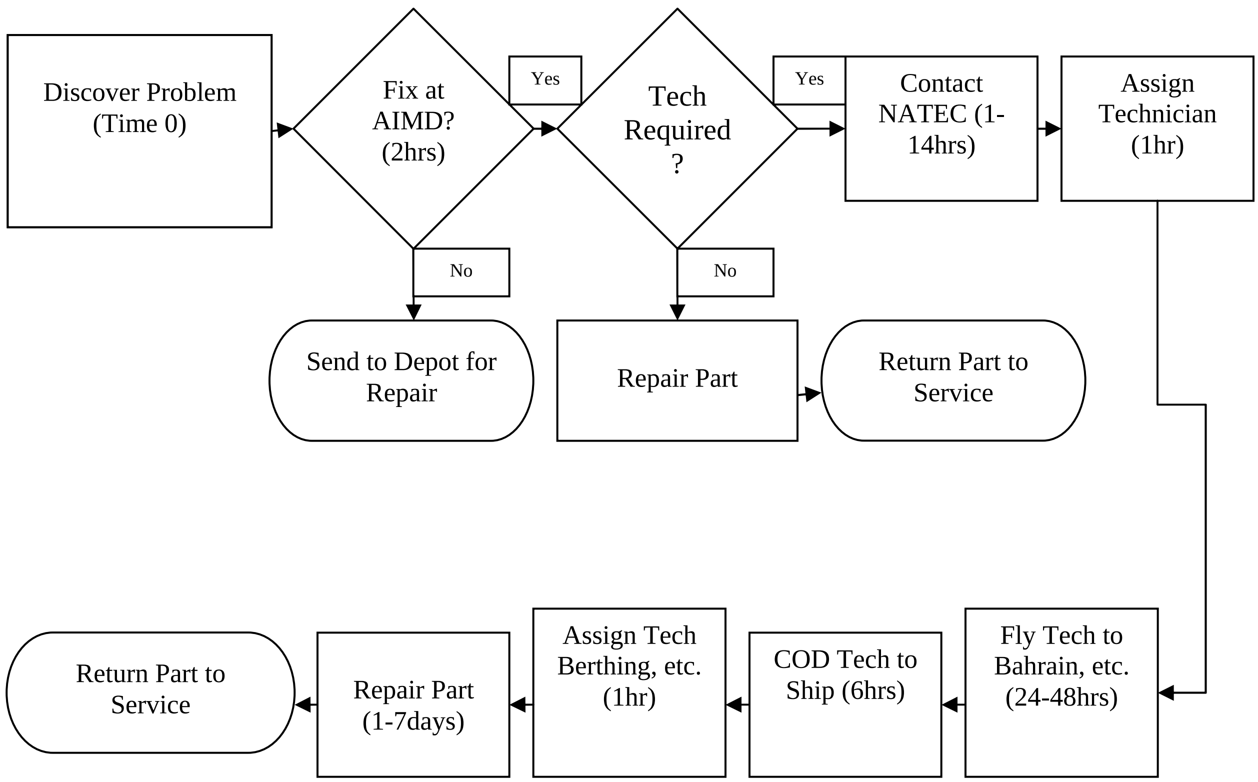

Figure 1. Existing Process

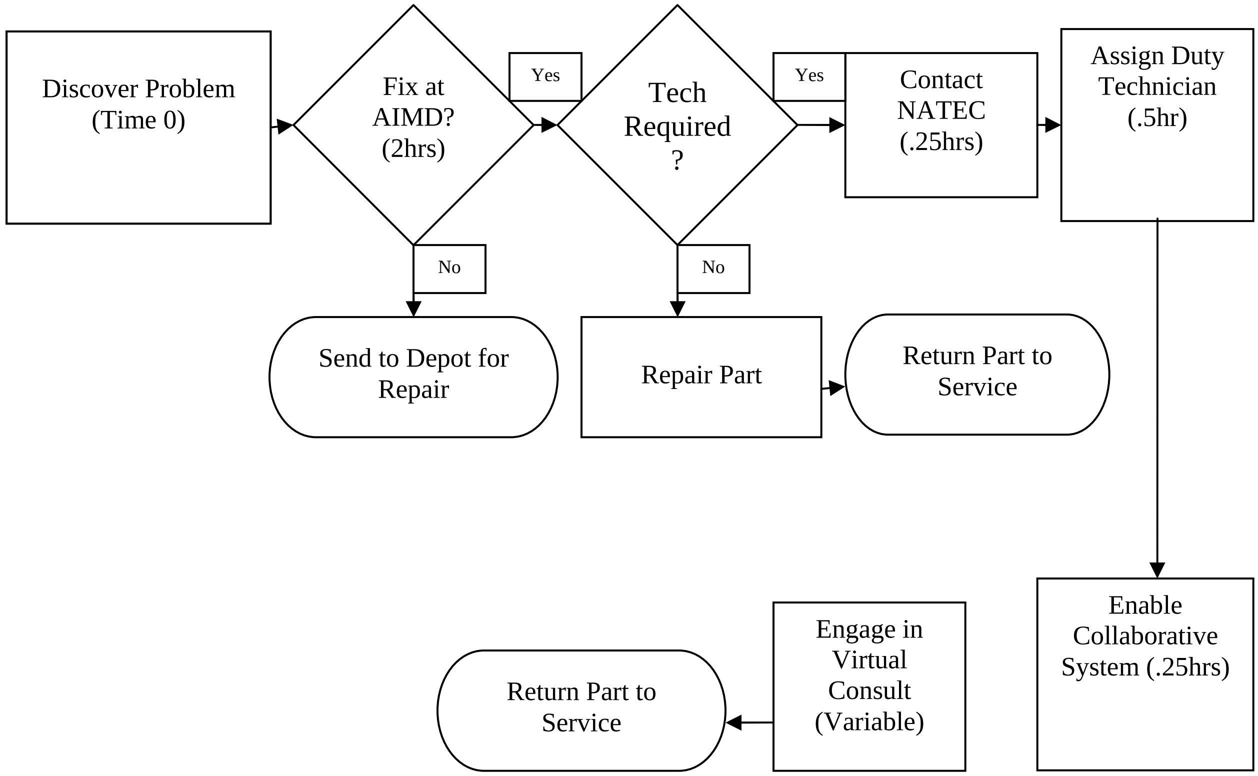

Figure 2. Proposed Process

B. SCOPE AND METHODOLOGY

The scope of this thesis will be to provide effective ways to use existing wearable computing and wireless technologies to develop a functioning system that will allow shipboard maintenance personnel to take advantage of these cutting edge technologies and leverage them to provide decreased turnaround times and expense to the Navy and DoD while maintaining or increasing production efficiencies across the board at the AIMD and squadron levels.

This will be accomplished through a review of the technologies available and their capabilities, a report of various experiments conducted with the wearable computing system, a cost and time savings analysis, an analysis of training that will need to be conducted to ensure maximum effectiveness at the earliest possible time and an analysis of the potential impact that the system could have upon personnel regarding morale and operational effectiveness.

The experimental aspects of the thesis will consist of functional tests in various environments including lab settings and various field environments in order to test the practical functionalities of the system in those various environments. Field environments will include land-based experiments and, if possible, sea-based fleet transit experiments.

Impact upon personnel could be gauged based upon surveys distributed to various maintenance personnel including junior and senior enlisted personnel. These surveys would necessarily pose theoretical questions regarding the proposed system since the actual system is not deployed at this time, but they would, nonetheless, provide a general feeling of how the system would be accepted initially by the maintenance community. A sample survey is included as Appendix A. This survey has not, at present, been distributed

C. SYSTEM ARCHITECTURE

1. Physical Architecture

The physical architecture of the proposed system consists of distributed nodes comprised of Xybernaut wearable computers worn by maintainers on deployed assets such as aircraft carriers. These wearable computers are connected via Wireless Access Ports (WAPs) using 802.11b protocol to the shipboard wireless Local Area Network (LAN). Shipboard local servers will provide some necessary software and database storage services to the system. The ship’s LAN will also provide the requisite routing services and gateway to the internet via satellite required for the collaborative process.

Once the internet connection is established data streams will flow to and from remote database sources for data entry and retrieval and to remote Groove servers for instantiation of the collaborative process. Data flows will continue to and from NATEC technical workstations and to and from Xybernaut systems across the internet to enable the collaborative process. The figure below details a graphical representation of the physical architecture of the system.

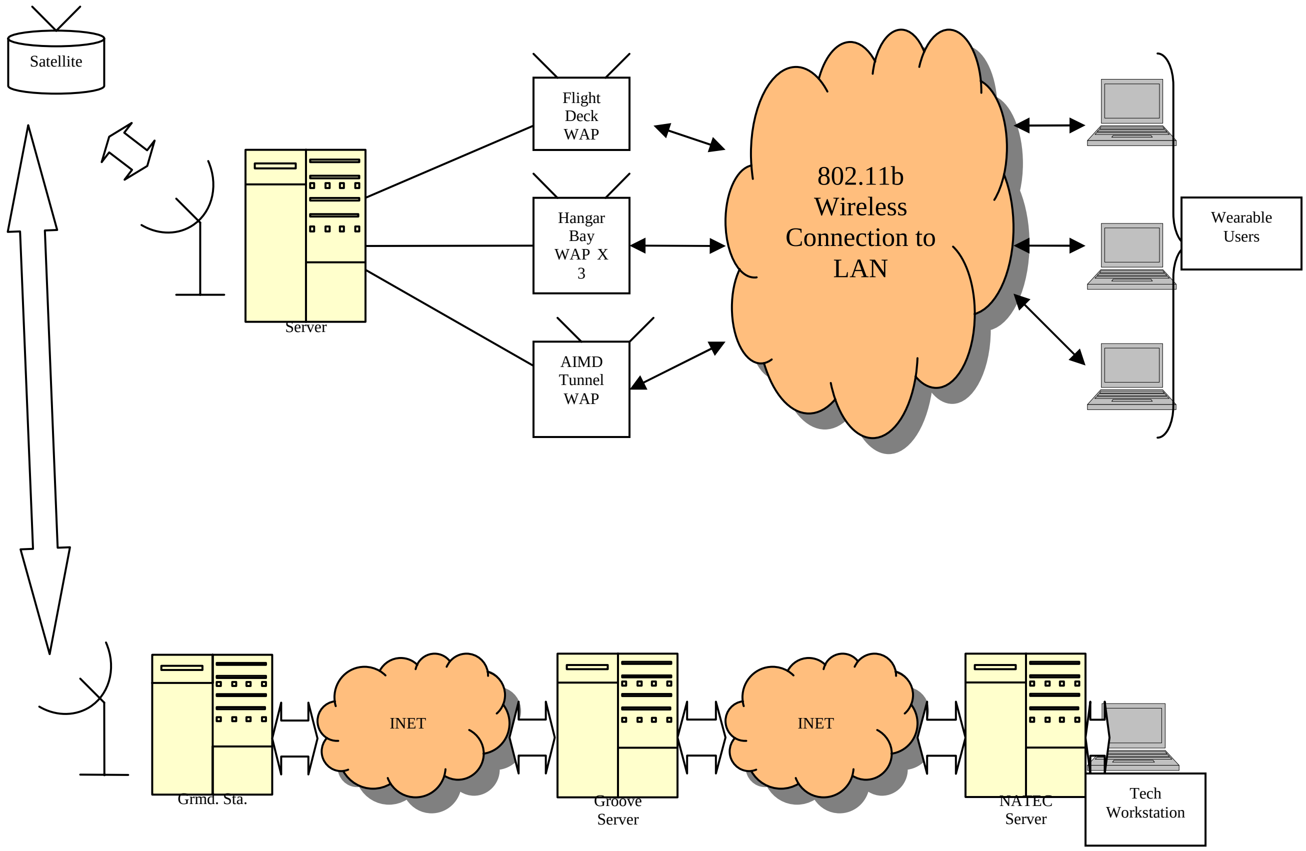

Figure 3. Physical Architecture

2. Software Architecture

The software utilized in the system is primarily COTS with one application, NALCOMIS being a Legacy system. The COTS software, in the form of the Groove collaborative system software is founded upon the OSI 7-layer model utilizing TCP/IP protocols for transmitting information across the internet. The proposed technical data repository, on the other hand, could be defined as a “blackboard” type architecture in which information is posted to a central repository and then retrieved on demand by a client. An in depth examination of software architectures is not within the scope of this thesis and as such will not be addressed here. It is sufficient for the purposes of this thesis to state that the proposed system takes advantage of various software technologies and their respective architectures and integrates them into a scalable fractal architecture that will readily meet the needs of deployed maintainers wherever they may be in the world.

D. INFORMATIONAL SOURCES

There is extensive literature available regarding wearable computing, augmented reality, intelligent agents, and collaborative technology. The literature consulted for this thesis provided background information on the various technologies that could later be integrated to form the realized system. This literature included corporate websites for Xybernaut Wearable Computing Systems, Groove Collaborative Systems, and BAE Technologies. It also includes periodical articles regarding the above companies and their products as well as excerpts from texts regarding the use of augmented reality and collaborative systems. These sources can provide the researcher with a substantial framework upon which to build and formulate new applications for the given technologies. This synthesis is the basis upon which this thesis is founded.

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II. TECHNOLOGY

A. WEARABLE COMPUTING

The new expedited maintenance system revolves around the incorporation of wearable computing into the maintenance program onboard deployed vessels. Wearable computers, such as the Xybernaut MA V, manufactured by the Xybernaut Corporation, are just what they sound like – computers that can be worn by individuals allowing them heretofore unseen levels of mobility and connectivity in the workspace. The MA V unit (MA stands for Mobile Assistant) is a ruggedized central processing unit that can be worn in a personal harness and can be equipped with a variety of peripheral devices depending upon the user's needs. The devices that will be incorporated into the naval maintenance system will be comprised of the central processor outfitted with a head mounted video display, boom mike, head mounted digital video camera and 802.11b wireless access card. Inputs to the device will be accomplished by either voice recognition commands and/or wrist worn keypad.

The MA V will be connected to the ship's Local Area Network (LAN) via a wireless connection utilizing 802.11b protocols and Wireless Access Points (WAPs) located throughout the ship. In the case of an aircraft carrier these WAPs, consisting of a simple unidirectional antenna, will be initially located in the hangar bays, forward AIMD "tunnel", aft in the jet shop and on the island at flight deck level. If the application proves successful, WAPs may be distributed even more widely throughout the ship to provide complete coverage. This is, of course, redundant in the event that a ship already has a wireless LAN network in place.

Wireless access to the ship's LAN will allow the maintainer to access all documentation and publications pertaining to his maintenance actions that are stored in a digital format. Currently the navy has transitioned its technical and maintenance publications to a CD-ROM format, but these can easily be uploaded to a local server in order to provide immediate LAN-based access to the materials. Utilizing this system the maintainer will be able to view all necessary publications and documentation through his head-mounted display without ever having to take his attention away from his work or go

looking for a publication. He won't even have to turn his head to reference a paper copy of a schematic as all information will be displayed right before his eyes.

A system similar to the Xybernaut MAV was tested by Georgia Tech University in August of 1996 to evaluate wearable computing in an industrial environment. Their system was comprised of

> A compact computer (about the size of a portable cassette player) that the worker wears on a belt…A microphone/earphone headset that allows the system to accept voice commands and to provide audio information while protecting the worker's hearing and keeping the worker's hands free for other tasks…A finger-operated pointing device that can be adjusted easily for right- or left-handed workers…A head-mounted display with a tiny computer screen that does not block the worker's vision.[1]

The Georgia Tech team experienced some success with the system, but expressed the hope that future developments in the areas of miniaturization and optimized voice recognition would further enhance the system. This technology has definitely improved in the past seven years and the Xybernaut system benefits from these advances.

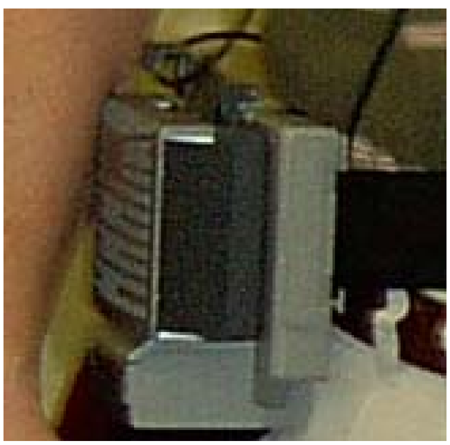

Figure 4. Xybernaut CPU

Figure 5. Heads-Up Display

B. MICROOPTICAL SV-3 HEADS-UP DISPLAY

This peripheral device is so integral to the Virtual Consulting system as a whole that it bears further attention. The SV-3 is a small, lightweight color VGA display unit with a resolution of 640 x 480 and providing 6 bit color. This low color capability is a constraint for streaming video that will be discussed later. The unit weighs only 35 grams which makes it easily mountable to a pair of safety glasses, as seen above in Figure 5.

The unit is small and light enough to be entirely comfortable to wear and yet provides the wearer with a view that is similar in experience to a 15 inch CRT hovering in front of one's eye. In tests conducted at the Georgia Institute of Technology test subjects indicated a perception of the computer display hovering in space in front of their eyes and, even though the display is opaque, they related a sense of it appearing that they could "see through" the display, almost as if it were transparently superimposed upon the real environment[2]. This is a boon to those who must concentrate on information both on the display and in the real environment. Of course, this is the purpose for which this system was developed.

Several advantages to the SV-3, in addition to its small size and light weight, include low power consumption, less intrusive nature than bulkier alternatives, such as laptop computers, and hands-free operation.

This last characteristic of the unit is of particular interest in the context of the proposed Virtual Consulting system. Allowing the maintainer to utilize both hands to conduct maintenance operations while receiving instructions and being able to access information, such as technical schematics, procedures, documentation, etc. is crucial to the optimization of the process. In terms of actual cycle time to complete a maintenance action this becomes obvious. It will take a maintainer less time to accomplish a task if he/she does not constantly have to turn away from the physical work to access information.

BMW has experimented with an augmented reality system for automobile technicians that overlays graphics on top of actual automobile engines utilizing this unit[2]. This system attempts to assist the technicians in their work by providing a virtual map for them to follow. Augmented Reality is discussed in the following section and is another facet of the Virtual Consulting system that shows great promise, if incorporated in a similar manner.

C. AUGMENTED REALITY

Incorporation of augmented reality (AR) is another exciting aspect of this change in the way maintainers will do business. Augmented reality will most likely be used in conjunction with collaborative technology which will be addressed later, but we may discuss the fundamentals of AR now without detracting from later discussion.

Augmented reality is a relative of the more widely recognized technology “virtual reality.” Unlike virtual reality, which completely immerses the user in a computer generated world, augmented reality combines what the user sees in the real world with computer generated graphics that “augment” reality with additional information. An example of this technology would be the ability of a technician to project a three dimensional view of a part to a maintainer’s headset, and then manipulate it, so that the maintainer can “see” what the technician wants him to do. This example will become clearer as we integrate collaborative technologies into our discussion.

Maintainers will also have access to a “dropdown” list of options that will be visible on their headsets. This list will be similar to what you would see in a Microsoft Windows operating environment. From a toolbar of general categories the maintainer would be able to choose options from each. For example, from a general category of “Documentation” a maintainer might be able to choose from “Maintenance History”, “Technical Publications”, or “Schematic Diagrams.”

Boeing is currently experimenting with and has demonstrated an augmented reality system that utilizes line drawings and text projected - by means of a system similar to the Xybernaut MAV - onto the real world. This system allows their mechanics to be “walked through” unfamiliar maintenance procedures by the software. “The system consists of a Polhemus fastrack electromagnetic tracker and Virtual Vision VCAP - 10000 HMD. The application was written in C++ as a standard Windows 32 application and has been ported to Linux.”[3]

The Xybernaut system that is currently being utilized does not have AR capability, but this is a capability that can be readily incorporated into the unit by means of the hardware listed above.

D. WEB-BASED DATA ACCESS

The ability to remotely access electronic documentation is a critical aspect of the Virtual Consult capability. By being able to access, display, navigate and search electronic documentation, the maintainer is able to maintain focus upon the job at hand rather than becoming distracted and having to physically pull his attention away from the procedure to reference paper copies of documentation.

Another compelling argument for locating technical documentation in a central data repository is the ease with which the information can be updated. The current method of issuing technical directives (TD's) and publication revisions is tedious, time consuming and incredibly inefficient. The incorporation of current TD's into local publications relies upon Technical Publication Librarians at multiple locations (every maintenance activity has one). By centrally locating electronic versions of documentation we will drastically reduce the human component and the inherent risk is ameliorated and efficiencies drastically improved. The effectiveness of maintainers and technicians alike is increased as a result of having access to up-to-date information in a much timelier manner.

BAE, a British company, has develop a software application it calls "trilogyView" that addresses this need for a secure central technical documentation repository that can be accessed from diverse locations by means of web technology. The following is a description of the system excerpted from an article in Signal.

> The program is a secure technical browser and a database. Initially it will be used to replace paper manuals for vehicle and weapon system maintenance. A user-friendly graphic interface allows easy navigation and access to support information and functions such as filters and hyperlinks. A desktop icon will permit maintenance, supply, and training personnel to locate information they need quickly with a suite of back-office software.
>
> The trilogy software package is based on Standard Generalized Markup Language (SGML) and Extensible Markup Language (XML) operating with Java plug-ins. The software exploits the availability of SGML data combined with the delivery capabilities of XML and uses a Java-base to deliver maintenance information seamlessly across a variety of computers and networks.[4]

BAE is a major partner in the Joint Strike Fighter project and so has close ties with both the United States defense and private sectors. The trilogi system that they have developed is being explored for possible incorporation into the JSF program. If this becomes a fact then we will have a foundation in DoD to build upon this system and possibly incorporate it into maintenance operations as a whole. This system could be proposed as a logical follow on to the NALCOMIS legacy system. Trilogi incorporates a

very flexible application protocol interface, according to its developers, that allows it to interface with a wide variety of applications. Whether that holds true for legacy systems such as NALCOMIS is not known, and somewhat doubtful. If it can, in fact, be made compatible with the existing system, then the additional value of this system linked with NALCOMIS is self-evident. If it cannot be incorporated into NALCOMIS, which is the more likely case, then trilogi still has enormous value to our maintenance efforts as delineated above. It is entirely possible that, working with BAE, the DoD could develop a trilogi based system that will implement all of the functionality of NALCOMIS and the data warehousing and rendering capabilities of the present trilogi system.

E. INTELLIGENT AGENTS

Intelligent agents may also be incorporated into the design of the new system, though to what extent they would be feasible or desirable is still a matter of debate. Intelligent agents are essentially software programs that attempt to act intelligently on behalf of the user and accomplish tasks that the user may otherwise forget to do, or are so time intensive that the user doesn't have the time or the inclination to do them.

Intelligent agents may be utilized in the given scenario to automatically initiate, complete and sign off Maintenance Action Forms (MAFs), update the NALCOMIS database, notify users of required maintenance on items that are the responsibility of the specific maintainer, or do data mining to find documentation or previous maintenance actions that may aid in the resolution of current maintenance problems. Incorporating these IAs within the system will necessitate compiling large databases or integrating existing ones and developing algorithms or trigger points to initiate the IA action. Consequently, much more time would need to be devoted to this particular aspect of the system before it can realistically be incorporated fully. Fortunately, IAs are not critical to the system functionality, but will eventually make it more effective and efficient as the system relieves the maintainer of some of the "paperwork load" involved in the maintenance process.

The company NeurOK has developed an interesting intelligent agent that uses a semantic algorithm to learn how to apply words in the context in which they are used. The following is an excerpt from a white paper on this new technology.

Intelligence for software agents means first of all the capability of understanding to some extent the *meaning* of information. This implies understanding the context in which the words are used, since the same word has different meanings in different contexts.

E.g.: the word **nucleus** *has different meanings in biology, mathematics, physics, military, sports, astronomy, etc.*

The context in its turn is defined by the same words. Thus one faces a recursive problem: the context is defined by the words, and the meaning of the words depends on context.

This situation drastically differs from when utilizing traditional databases, where each entity is completely characterized by the set of its pre-defined features.

The solution is based on proprietary patent pending *learning algorithm*, which automatically builds up the self-consistent set of *semantic categories*, allowing for comparison of the meaning of pieces of information: queries, phrases, texts.

This set of categories depends strongly on the *learning corpus*. Collections with different topics will result in different set of categories, each optimized to the given subject. It makes it possible to educate the agents having their expertise in various areas. Note, that this learning technique is completely language independent. The meanings of the words are extracted from the way they are used, independent on the nature of the language. Moreover, using multilingual corpus one can teach agents to understand relations between the words in different languages, paving the way for cross-language applications.

Semantic categories can be thought of as the axes of the *semantic space*. The meaning of each word or text is represented by their coordinates in this space. Those coordinates indicate the relation of the given piece of information to each of the basic meanings – semantic categories. The distance defined in this space gives us the measure of similarity between the contexts of textual information. Note that this measure takes into account dependencies between the words, so that using various synonyms does not change the meaning.[5]

The algorithm that is used is described as follows:

…one starts with the random set of categories, when all the words are randomly distributed among a predefined number of *K* semantic categories. The semantic vectors of the learning corpus are then clustered in the same number of *K* clusters. These clusters first accumulate the texts according to similarity of the terms usage, all terms treated separately, while interrelations between the words are negligible. At the next iteration those clusters are defined as the new axes, and semantic meaning of words are updated, so that the words appearing in similar contexts obtain similar semantic representation. The procedure is then iterated. Each such

iteration provides more and more accurate meaning of the words, taking into account the relations between the words, found at the previous one.[6]

This technology, coupled with remote database access to NALCOMIS, could provide invaluable increases in efficiency by allowing maintainers to automatically update database records and, possibly, allow the database system to automatically provide additional pertinent information to the maintainer regarding related maintenance.

F. COLLABORATIVE TECHNOLOGY

Collaborative technology is at the core of what makes the entire system feasible. Groove Networks has developed and fielded a software program that is designed to allow geographically dispersed individuals to communicate in real time via voice over IP (VoIP), and real-time chat text . The software also has file-sharing and application-sharing capabilities. Essentially, individuals are able to communicate and share visual, audio and data-based communications over the internet in real time. This technology will be combined with streaming video capability developed at NPS to provide a full spectrum of sensory inputs to both the deployed maintainer and the shore technician. This translates into a “virtual consulting” capability for NATEC technicians relative to deployed assets.

The incorporation of collaborative technology and wearable computing into the naval maintenance system has the potential to revolutionize the way that the navy, and potentially the Department of Defense, conducts maintenance operations at sea. By utilizing this technology the navy can reduce dramatically the turn around time that exists for maintenance that requires technical support. In essence, the technician can maintain a “virtual presence” onboard the deployed vessel without ever leaving his office.

III. TRAINING OF PERSONNEL

A. TRAINING

Thorough and timely training will be a key issue for successful implementation of this system in the Navy and DoD. The Navy has a history of relying upon on the job training (OJT) to provide the bulk of the training opportunity for its sailors. OJT is a great way to learn a skill, but when you are dealing with advanced technologies such as augmented reality and collaborative technology there must be some formal schooling involved in order to fully exploit the technology and gain maximum effectiveness from its use.

The training should encompass two distinct aspects - the first being familiarization and qualification on the hardware and software systems. This qualification would be set up as a standard part of the curriculum at appropriate A-schools for those who enter into the Naval Service after implementation of the system. This additional requirement should add no more than one additional week to the length of the A-school curriculum. For those who are already engaged in the Service in rates that require the use of the system a separate school should be established through CNET in order to train those individuals. A duration of one week should be sufficient for all aspects of the training.

The second aspect of the training will comprise a spectrum of communication skills that will be required to accurately and concisely convey information in a virtual environment. Personnel will be trained utilizing practical scenarios designed to engage them in using descriptive language and applied listening skills.

The result of attending either an appropriate A-school or the separate class will result in certification on the system. Personal Qualification Standards (PQS) will be developed to track and record individual progress and certification on the system.

1. System Training

Maintainers who are expected to utilize wearable computing systems such as the one that this thesis addresses should be required to attend formal classroom training as well as practical application exercises as an integral part of their qualification to use the

gear. The classroom training should include familiarization with the equipment and the software technologies employed to conduct virtual consulting with technicians. The limitations of the hardware should be addressed to include range of the wireless antenna, possible sources of interference, durability issues, care and maintenance of the gear and so forth.

Practical exercises should be conducted in a controlled setting to allow students to experiment with the technology and allow them to experience and "get the feel" for conducting virtual consult activities. They should also become familiar with the wearable computer's operating system (Windows 2000 Professional or Windows XP) and be able to access all of the databases available to them either locally or through internet connections.

These practical exercises should be conducted by personnel who have been fully trained and are comfortable with the wearable computer system and the technologies being used and are also familiar with the type of maintenance being simulated. This will facilitate a more realistic experience for the trainees and should result in a more effective and efficient training experience.

As with any skill, the ability to use this system effectively can be degraded though lack of use. For this reason, regular requalification tests should be incorporated into the PQS for the system to ensure that the maintainer is current with the technology and skills involved in its use.

2. Communications Training

Just knowing how to use the gear is not enough. Maintainers and technicians alike must be able to accurately communicate information verbally in order to accomplish the mission. This can be quite a challenge. As individuals we all have a range of different experiences and backgrounds. Gaps in communication can result as a byproduct of one individual making assumptions about what another understands or comprehends based upon our own experience. For example a mechanic may tell a person that they can adjust the idle on their car by adjusting the idle set screw on their carburetor. This may seem simplistic to an experience mechanic, but to someone who has never worked on a car before, they may not even know what the carburetor is, much less which screw is the idle set screw!

Communications training must include the use of proper querying techniques as well as listening techniques so that each party involved is sure that they understand both instructions and what is being asked. Descriptive communication techniques should be developed to facilitate the process of understanding between the parties involved.

The figures below are a graphical representation of the training process as it may be implemented. It outlines the training process of a new recruit coming out of boot camp directly into A-school. The training process for the technical aspects of the system as well as applicable communications skills are taught concurrently with the normal vocational training that takes place in the A-school environment.

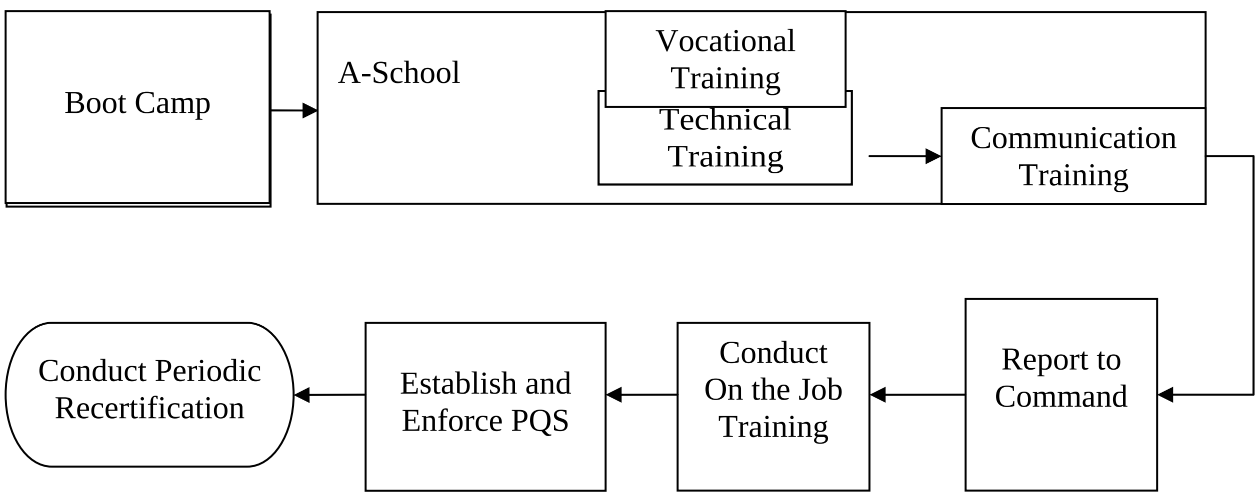

Figure 6. Training Process (New Recruits)

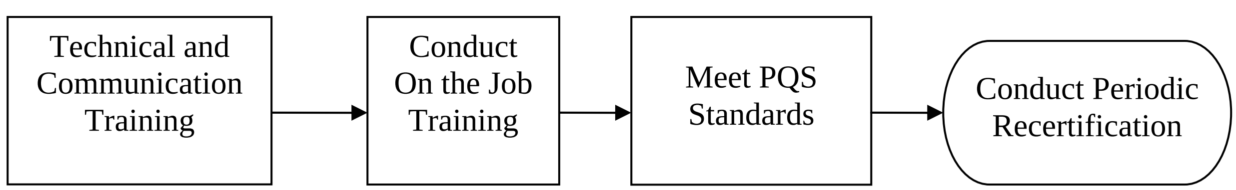

Figure 7. Training Process (Technicians and Fleet Maintainers)

B. TECHNICIANS

Up to this point we have focused primarily upon the deployed maintainer. The other half of the picture is the technician back on shore. Technicians must share in some of the same training process as the deployed maintainer. They should at least be familiar with the wearable computing systems being utilized by the maintainers, though proficiency with them is not necessary. What is most critical for the shore-based technician is a thorough understanding of the collaborative technology (Groove) that is being employed and the communications aspect of virtual consulting.

Groove Networks will allow the technicians to communicate real-time with the maintainers via a variety of mediums – chat, voice, file sharing, etc. Streaming video software will also be incorporated into the system allowing technicians to "see" what the maintainers aboard the ship see. Technicians must be thoroughly familiar with all of the options this collaborative technology makes available to them in order to maximize their own efficiency. While the ability to stream video from the maintainer to the technician and the ability for the technician to send images back to the maintainer will greatly enhance their ability to communicate effectively, technicians will still need to develop excellent descriptive communications skills in order to ensure that the maintainer is able to successfully and efficiently accomplish the task as dictated by the technician.

IV. IMPLEMENTATION AT SEA: THE PROPOSED CHANGE – A NEW PROCESS

A. THE PHILOSOPHY

The change proposed is not a sweeping organizational change that will require a fundamental shift of organizational attitude, but it is one that will require organizational support at relatively high levels in the naval command structure. This is due to the nature of the organization and how things typically "get done" in the navy and DOD as a whole. Changes normally require funding to implement that change and this change will be no different. There will be funding requirements for the purchase of necessary hardware and software and training that will be an integral part of the change process.

The implementation of this change will reflect, in some ways, the technological change made by the First National City Bank Operating Group in Todd D. Jick's "Managing Change". Contrary to John Reed's approach, however, I would advocate a policy of parallelism rather than one of abrupt succession. Reed accomplished his turnover of technology in a weekend[7], allowing for little or no incubation period in which the new technology might "take hold" and "grow" upon personnel. In the case of the navy, parallelism is a necessity. A deployed carrier cannot afford not to have a contingency plan that will allow it to get the job done – even if that means reverting back to the "old way of doing things" while bugs get ironed out in the new system. The challenge, then, is to ensure that the reversion does not become a permanent circumstance. This is why the implementation of this new technology and process must have active support at all levels to ensure that the process of transition is supported and enforced in such a manner and to such a degree over a sufficient period of time that it becomes "the Way".

The philosophy of this change must be, then, that the upper levels of the command structure have a vision of a new streamlined naval maintenance program that can positively affect the capability of the navy to wage war. Therefore the change is good and worthy of both sustained fiscal and managerial support. This vision must be instilled in the entire organization through a campaign of thorough briefing and training for those involved. Gordon R. Sullivan says in his book "Hope is not a Method" that "Doing the

same thing that you have always done – no matter how much you improve it – will get you only what you had before.”[8] This is a very important distinction and one that is not always obvious on the front lines. We in the military are, to a great extent, creatures of tradition. While we constantly seek to improve performance, it is sometimes difficult to admit to ourselves that a different way may be better. Combined with natural human inertia, this can be a challenging obstacle.

B. IMPLEMENTING THE CHANGE

1. Type Commanders

Even though this new technology may be the latest in “feel-good, whiz-bang” and there doesn’t appear to be any real down side to implementing the technology, doesn’t necessarily mean that it will be welcomed with open arms by the Navy or DOD. As was mentioned before, organizational inertia can be a very difficult thing to overcome – especially in an organization as large and steeped in tradition as the U.S. Navy.

The change initiative must start with the type commanders. Type commanders are Flag Officers who have overall responsibility for a platform type, such as carriers or a type of aircraft. They are also instrumental in securing funding for their respective platform types. Once these individuals are convinced of the importance and impact that this new technology can have upon their assets’ mission accomplishment, the change process can truly begin. Without support from the highest levels the change will seem like just another “experiment” with new gadgetry and may, or may not, take hold. Continued top-down support for the change process is essential to its success. This is contrary to the belief that many have that “buy-in” needs to come up through the lower ranks.[9] While buy-in at the lower levels is also critical, it has to start at the top. Without senior officer support the effort is doomed to failure.

As the senior leadership involved, the type commanders must resolve to undertake a process which will allow them to achieve this level of necessary “buy-in”. This process may be different for each individual and organization, but there are several steps and considerations that each should carefully consider in the process of deciding whether or not they will support the change process. These steps are outlined as follows:

1. **Have a Vision Built on Values -** An organization must have a clear vision of what its role in its environment is at present and what it wants to accomplish and become in the future. Vision is the most important and fundamental aspect of any undertaking. It equates to having a destination in mind when embarking on a journey. If you don't know where you are going, chances are you will end up somewhere other than where you need to be. Build your vision and its consequent strategies upon your organization's core values. Do not allow your organization to compromise its integrity for the sake of short-term profit or progress.

    In the case of implementing this new technology, the vision of a Navy reflecting increased levels of mission readiness is the key component. There is not a conflict of values, but simply a decision to be made as to whether implementing the given technology will take the Navy to where it needs to be in the future.

2. **Develop a Strategy –** Develop a cohesive and intelligent plan to accomplish your vision. If the vision is the destination then strategy is the roadmap that will take you there.

    Type commanders normally delegate the "nuts and bolts" of implementations to individual commanders, but the type commanders need to promulgate an overall plan to the individual commanders regarding what they expect. In this case this should include a regular reporting scheme regarding the commanders' implementation of the new technology and how it has affected the commands' readiness. These reports should include hard numbers reflecting maintenance turn-around times, down-times, expenses related to maintenance and incorporation of the technology, etc.
3. **Set Goals –** Set reasonable and attainable short-term and long-term goals that will give both management and lower level employees the opportunity to experience success while moving forward with the developed strategy.

    Overnight, overwhelming success can only be hoped for, but not expected. Type commanders should encourage and require commanding officers to set realistic goals for their commands that will allow their sailors to experience success on a regular and sufficiently frequent basis.

4. **Get People Involved -** The fastest way to win over the majority to your cause is to allow them the opportunity to feel successful early and often. This is in many ways the most difficult aspect of the change process because it involves a great deal of planning and implementation on the part of management to develop avenues that will allow both themselves and their subordinates to feel that they are contributing to something tangible and not just a “flash in the pan” management whim.

   Involvement will be an integral part of this particular change process. The sailor on the “front lines” will be the one actually utilizing the technology and so will be fully engaged in the change process. It is essential, however, to make sure that the sailors are involved in the feedback loop as well as just using the gear. A tool is only as good as the person who wields it and the maintainers must feel that they are able to voice concerns or suggestions that they may have that can be utilized in a productive manner. Of course there will always be those who don’t have anything good to say about doing things differently, but if the upper echelons keep “the press” on, they will eventually acclimatize.

5. **Commit for the Long Haul –** Change will only take place if the organization is committed to make it happen. This requires support from the highest levels of management. The lower ranks will only be able to overcome their initial resistance to change if they see that management is united and committed to incorporating the change over the long term. It takes years to change the culture in a large organization and so management cannot expect things to happen overnight. The management structure must expect and support a long-term and in many cases painful transition from “how things used to be” to “how things are going to be.”

   Senior enlisted and division officers and department heads must not allow themselves to be swayed by their sailors’ resistance to change, even though they, themselves, may also be affected by inertia. The entire command structure must be a cohesive unit and be committed to seeing the change effort through.

6. **Hold People Accountable –** Hold those responsible for implementing change accountable for the progress of strategic goals. This goes both ways. There must be an appropriate reward system in place as well as consequences for those who do not put forth the effort required to successfully implement the required changes.

   This is a basic concept that is all too often ignored. If a person, or an organization, feels that it doesn't matter whether something is accomplished or not - or that they won't be held responsible for its accomplishment - it is very likely that the action item will not be accomplished at all. Inertia is very difficult to overcome without some sort of exterior influence – a "push", so to speak. This push need be nothing more than the requirement to report one's progress. Those in the armed forces are a proud lot and many consider a sub-par report to be an indication of personal failure. For these, the requirement to simply report may be enough to ensure positive action. For others who are motivated by extrinsic reward a consequence, both positive and negative, must be in place for outstanding or sub-par results.

7. **Review Often and be Flexible –** Review both vision and strategic plans often for appropriateness and fit to the organization and its environment. Do not be afraid to be flexible. A proponent of change who cannot adapt his plan of organizational change to successive changes in environment would seem rather hypocritical.

   Type commanders must be sensitive to the changing environment that their commanding officers act in. This necessitates the formal review process outlined above. Technology is constantly changing and improving and senior leadership must be receptive to the idea that different and better means may become available with which to accomplish the mission. However, deviation from the organizational vision and strategic plan must be done carefully and within the context of improving upon the stated goals and not just changing strategies on a whim.

2. Individual Commands

Commanding officers must be held individually accountable to the type commander for implementing the necessary changes within their respective commands. This is the fundamental level at which the new system will either be “made” or “broken”. Commanding officers have enormous power and influence within their area of responsibility. A supportive CO can make all the difference when faced with friction from within his command. By holding his department heads accountable he can ensure that the proper steps are being taken to integrate the new technology into his command where it is needed.

While military officers do have the authority to order troops to obey their commands and thus could require obedience to the type of change implemented by incorporating new technology into an already existing process structure, it is rarely advisable to undertake this strategy in a peacetime environment. It is more advisable for commanding officers to realize that there will be a certain amount of resistance to change and expect it. This resistance can, in fact, be beneficial if it is used to improve the change process. When members of the organization seem to be resisting change they may just be administering a healthy dose of criticism to a process that the “higher-ups” say is going to be vastly improved. This criticism, if constructive, can be used to improve the process and address concerns related to the new process or technology.[10]

Some valid concerns that the front-line maintainers may have could include training on the new technology, which will be covered later in this paper, and the “warm fuzzy” feeling of knowing that the technician is physically right there and able to physically take over the process if the maintainer gets flustered or doesn’t understand the technician’s instructions. These are important and valid concerns that must be addressed and anticipated by command officers, their department heads and division officers. Those in the upper levels of the chain of command should make a concerted and conscious attempt to not become angry or frustrated at what they may perceive as resistance, but rather recognize it as a natural reaction to change and approach it as such.

C. RESISTANCE TO CHANGE

Technicians may also have reasons to resist change. Some may enjoy the experience of being deployed for limited periods of time. Others may value the additional

moneys that come from the overtime incurred by deploying, and some may simply feel that they need to be physically present in order to ensure that the job is done properly. Still others may feel that this new technology presents a threat to their job security by allowing maintainers to gain proficiency in areas that would otherwise be the sole responsibility of the technician.

Individual commanders of NATEC facilities must address these concerns with their technicians and try to ameliorate them with the advantages that the technology provides relative to quality of life and mission accomplishment and efficiency across the Navy and DOD. For those who enjoy the “old way” this may be challenging, but for those who don’t enjoy being called away from friends, family and loved ones on short notice to deploy to unfriendly waters while working 12-hour days and 7 day work-weeks this “new way” may actually be well received. No matter the type of reception, feedback to the new process must be perceived as being wanted and important to the command.

D. REALIZED IMPROVEMENTS IN THE SYSTEM

1. Efficiency

Improving efficiency is one of the key drivers for change. By incorporating this new technology the Navy will see a decrease in turnaround time for critical components and, possibly, a corresponding decrease in man hours expended. This may not initially be the case as there will most likely be a learning curve as maintainers and technicians adapt to the new system, but in the long run we would anticipate that with the increase in communication abilities between technicians and maintainers and the increased skill level of the maintainers as a result of working so closely with the technicians that there will be a drop in the man-hours expended per included maintenance action.

Increased time savings will be realized as the result of maintainers not being required to wait for technicians to actually arrive on scene. As previously discussed, this can take a significant amount of time and constitutes a major portion of the turnaround time for technical assist maintenance.

2. Cost Savings

The new system will also decrease costs for the Navy related to technical assist maintenance. By eliminating the need to fly a technician to the deployed asset, berth him/her in a hotel overseas for a number of days, and pay them per diem and overtime the

Navy and DOD stand to reduce technical assist costs by a significant amount. This savings can translate into thousands of dollars per week depending upon the technician's salary and location of the deployed asset.

The cost to incorporate the wearable computing system can be recouped in many cases within one or two deployment periods. This is so due to the fact that the technology is available for around $5,800 per system. Since there is no need for each maintainer to have his own wearable computer, commands could get by with significantly fewer units than the number of maintainers in the command.

V. POTENTIAL MORALE IMPACT UPON PERSONNEL

A. TECHNICIANS

The incorporation of the new system stands a very good chance of improving the morale of both deployed sailors' and shore-based technicians. Not only is the new technology "cool" and "whiz bang", but it allows the technicians the ability to consult directly from their office vice having to pick up and deploy in order to provide a fix for a technical problem. This involves much less time away from home, friends and family for the technician. This resolves into less stress and a better quality of life.

There are, however, possible negative morale impacts that must be considered. One of these would be the reduced ability of technicians to earn additional monies in the form of per diem and overtime pay normally associated with technical assist visits to deployed vessels.

Another consideration has to be that some technicians may feel threatened by the fact that they will essentially be providing additional training to maintenance personnel by walking them through procedures. Technicians may feel that their jobs are at risk if maintainers begin to feel confident that they can resolve more advanced problems after having been walked through them several times. This issue would have to be necessarily addressed through a policy of always requiring technicians to be involved in repairs that they would ordinarily be called in to service.

The final factor involves the necessity of manning a duty desk or having a duty technician on call. In order to maximize the effectiveness of the system and reduce turn around time to a minimum maintainers would have to have access to technicians 24 hours a day, 7 days a week. This would require a shift in philosophy from an environment of normal day shift work to one of a more military nature where there is always someone on call who can be contacted at a moment's notice. Note that this can be accomplished with a pager or similar device. The object is to cut response time to a matter of a few minutes to an hour or so, rather than days. While to those of us in the military this does not seem like a major shift in thinking, for personnel in the civilian sector who are not used to this type of work structure, it may present a period of adjustment and initial resistance.

B. SAILORS

For deployed sailors the new system makes their job easier in a number of ways. It provides them a platform to easily carry all of their pertinent technical publications, a means of scheduling and providing automated reminders for important maintenance actions, and a way to obtain real-time technical expertise without having to go through the delays normally associated with obtaining this support.

For the sailor, this translates into a better work experience by allowing him to accomplish his tasks in a more efficient and effective manner. This makes him more productive and valuable to his superiors. In the most practical interpretation, if your boss is happy, you are happy. This technology has the potential to allow the sailor to more easily keep his boss happy.

There is the potential for an “impatient” mindset to develop, however. A belief that technical response should be instantaneous may develop and this should be actively addressed. While response should be much swifter than the previous system, it will still take a certain amount of time to contact the necessary technician(s) and establish the virtual connection. As previously mentioned, the object is to cut response time to several minutes or at most an hour, or so, if the technician has to report back in to the office after being “beeped”.

VI. EXPERIMENT PROCEDURES AND RESULTS

A. PROPOSED PARAMETERS AND PROCEDURES

The proposed format for the experiments involving the Xybernaut wearable computer system is outlined below. The format consists of a five phase process with the last two phases being repeatable for successive experiments and the first three phases related to the initial setup of the system.

1. Phase I – Assembly

The first phase will comprise assembling the Xybernaut gear into its predetermined configuration. This will include verifying that all requisite hardware is present and in good working order. The requisite hardware includes the following:

1) MA V Central Processing Unit
2) Microvision head mounted display unit
3) Head mounted digital camera
4) Head mounted boom microphone
5) 160-key wrist worn keypad
6) Symbol 24 802.11b wireless LAN card
7) Assembly and mounting harness

2. Phase II – Functionality Test

The second phase will be a general test of the system functionalities. This will include the following:

1) Test preloaded software (OS and component drivers) for functionality.
2) Configure and test access to NPS wireless LAN.
3) Test and confirm range limitations of 802.11b wireless card.

3. Phase III – Incorporation of Groove Collaborative Technology

Phase III will incorporate Groove collaborative software into the Xybernaut wearable computer system. Groove will be loaded onto the MA V and will then be tested for functionality and operational efficiencies. These will include the following:

1) Test for real-time chat capability and speed utilizing keypad input.
2) Test for real-time voice capability and intelligibility.

3) Test for streaming video capability and establish minimum acceptable frames per second rates.

4) Test FTP protocols and establish acceptable file transfer rates between Xybernaut and remote servers/stations.

4. Phase IV – Practical Experiment

Phase IV will consist of conducting a practical experiment(s) incorporating all of the established functionalities of the Xybernaut/Groove system. The experiment will be designed to follow, as closely as possible, a comparable sea-based evolution. The design of the experiment is proposed as a role play as follows:

1) Player A (Xybernaut user/shipboard maintenance person) identifies a problem with a piece of equipment that he cannot solve on his own and calls Player B at his office.

2) Player B (Shore-based technician) requests a collaborative virtual consult session after determining that he can most likely walk Player A through the “fix”.

3) Player A dons the Xybernaut wearable computer and establishes the collaborative Groove workspace link via the NPS LAN.

4) Player B enters the Groove workspace and Players A and B begin communicating via voice, video and, if necessary, file sharing.

5) Player B receives pertinent video and voice information from Player A and communicates back necessary instruction via voice communications and/or appropriate file sharing.

6) Player B supervises the repair procedures via streaming video to ensure proper maintenance action is accomplished.

5. Phase V – Results

This final phase will comprise a written report of the results of Phase IV to be included within this thesis. The experiment results will describe and delineate pertinent data points and will contain an evaluation of whether the experiment was deemed to be successful based upon technical, practical and human factors deemed relevant to the achievement of system goals and objectives.

B. INITIAL RECEIPT AND CONFIGURATION

Upon receipt of the wearable computer hardware from Xybernaut an initial functional check was made of the main unit and the majority of the peripheral equipment including the Symbol wireless LAN card, the finger mouse, the wrist key pad and the head-mounted display. It should be noted that Xybernaut had to be contacted regarding configuration of the unit for the heads-up display as it would not function until the unit was configured to work with it. This included adjusting the resolution settings in the Operating System to levels acceptable to the display unit. This adjustment required the unit to be connected to a CRT in order to perform these adjustments. While not inherently difficult, this process was inconvenient and frustrating from the aspect that one would assume the unit to already be properly configured for the application for which it was purchased - namely, to function with the heads-up display unit. This aside, the unit works well with the display. The boom microphone software, including the voice recognition software, has been loaded and the functionality test included in the software package indicates that the microphone and earpiece are working properly, but this has not yet been tested in the Groove environment. All indications are that it will work as intended. The camera has not been tested yet as the streaming video server is not yet online. When the software has been uploaded to the server and is functionally tested testing of the camera's capabilities will be performed.

After the functional tests had been concluded the unit was configured for wireless access to the NPS wireless LAN. This was achieved without incident, however it should be noted that the heads-up display resolution is not quite high enough to confidently see small single-character displays, such as when inputting WEP keys, registration numbers, etc. The top edge of the display also appears a little distorted. This is most likely due to the curvature of the display optics. After configuration the connection to the wireless network was successfully tested and the unit was able to function normally on the network and was allowed access to all authorized network functionalities including high-speed internet access.

The unit's connectivity was tested at NPS by moving around the campus "quad" courtyard and through the various buildings on campus that surround the "quad" over the

course of several days. Connectivity generally was good and seemed to be on a par with other mobile wireless devices such as laptop computers.

Subsequent to its initial wireless connectivity testing Groove Collaborative Systems software was downloaded onto the unit and a separate laptop in order to test the functionality of the unit in a collaborative environment. This functionality was tested in a lab setting in the Gigacode Lab with excellent (11Mbps) wireless connectivity. Initial testing was made by sending text messages back and forth between the unit and a Dell Latitude X300 laptop computer with a Pentium M mobile processor. Future testing will incorporate more distributed locations for testing the wireless link and capabilities similar to the initial wireless testing for functionality. This will be followed up with network analysis tools to ascertain data throughput, packet loss rates and average transmission times. The other functional aspects of the Groove environment will also be evaluated, to include voice transmission, file sharing and application sharing.

C. CAMP ROBERTS EXPERIMENT

The Xybernaut unit was first tested in an actual field environment on 10/28/03 and again on 10/30/03 at Camp Roberts in Central California. The environment was an arid prairie-like region with rolling hills surrounding a wide, relatively flat area sufficient to locate a small airfield. The experiment involved special operations ground forces transmitting text messaging between themselves and a communications center while concurrently receiving video telemetry from an overhead UAV. The Xybernaut aspect involved ascertaining whether or not the unit could function in a field environment and be able to communicate with the comm station and ground units and receive the telemetry from the UAV.

The unit was able to successfully connect to each of the three wireless networks available at the experiment; GU1, GU2 and AirACC. These networks represented Ground Unit 1, Ground Unit 2 and the UAV, respectively.

The Xybernaut unit was able to freely communicate with the ground unit and communication stations once the NetChat software was downloaded onto the unit and the unit was in close enough proximity to the ground units to receive sufficient signal strength. The unit appeared to be very susceptible to changes in orientation of the unit in regards to the signal origination point. The capability of the unit to successfully receive

sufficient signal was tested by traversing an area between the ground units and the communication station until sufficient signal was received to allow the Xybernaut unit to communicate with the various other participants. Once connectivity was established the unit would be reoriented by rotating it through 360 degrees. It was discovered that a change of approximately 45 degrees from optimum would create a state of intermittent connection and a change of approximately 90 degrees would cause total signal loss. The range from signal origination was approximately 100 meters. It is not certain what the signal strength from the originating unit was at the time of testing, however a range of 100 meters should be well within the Symbol card's capabilities and it was interesting to find that the wireless connection was so unreliable at this proximity. Contributing factors may include multipath interference and RF interference from a nearby electrical generator.

Video feed from the UAV was tested using MPEG4 video software. Unfortunately, this link was only enabled on a part-time basis and coordination between the communications center responsible for enabling the link and the individual experimenters was challenging. The Xybernaut unit was able to establish a momentary link and receive some splotchy feed from the UAV. This was not a shortcoming on the part of the Xybernaut unit as the comm center received the same telemetry at that time. The feed errored out after several seconds and the link was terminated.

The experiment shows that the Xybernaut unit can establish working wireless links in tactical settings, but there needs to be work done to improve its range and reliability. The Symbol card is a very compact unit and could benefit from an extended external antenna to extend its range in these types of environments.

D. INTERFACE ISSUES

The user interface could also use improvement in the areas of monitor resolution and element protection. If the heads-up display monitor gets dusty, for instance, it adversely affects the operator's ability to see the display – much more so than a conventional CRT. This problem may be solved by incorporating an adjustable dust shield that would form a seal between the display optics and the glasses the display is mounted on. This could be a soft rubber shield that would mold to the exterior of the glasses in such a manner as to allow for the tri-axial adjustment of the display unit itself.

The unit could also benefit from integration of wireless peripheral devices. It is awkward having wires for the various peripheral devices hanging around one's person and this could be resolved by incorporating Bluetooth or another wireless protocol that would not interfere with the 802.xx protocol used for data transmission to establish connectivity to the peripheral devices. This would ensure a feeling of true "wireless" freedom for the operator and make the unit much more streamlined in an operational sense.

The experiment was a success in that connectivity was positively established and several strengths and a few weaknesses were identified that can be further evaluated and acted upon in order to configure an optimally functional system that will meet the needs of the Navy and the Department of Defense.

E. CONNECTION TO STREAMING VIDEO SERVER

In late November after the Gigacode Lab streaming video server was set up the Xybernaut computer was connected to the server to test its ability to process streaming video and voice over IP.

The streaming video server utilizes an interface that appears as a series of "doorway" icons that appear on the computer display after the user enters the appropriate IP address to access the server site. There are separate sites for recording video/voice information for later retrieval and for streaming voice/video. The streaming site was the one utilized for this experiment.

To use the site the user simply ensures that he has a compatible microphone and digital camera capable of broadcasting streaming video enabled on his system and selects a "doorway" and the streaming process begins. Any other individual that wishes to connect to the "room" simply clicks on the "doorway" and, assuming he also has the requisite microphone and camera, begins streaming his voice and video back into the "room" as well. This results in a virtual real-time communications capability utilizing IP protocols.

This experiment was conducted using the Xybernaut wearable computer system connected to the NPS wireless LAN in the Gigacode Lab space in Root Hall Room 202. The Xybernaut system was connected to a standard 17" LCD monitor for this phase of the experiment. The second node was a PC hardwired into the NPS Ethernet LAN. The

PC was located in Root Hall Room 223 several hundred feet away. The experiment proceeded flawlessly with more than adequate video resolution and minimal jitter. Voice transmission experienced about .5 – 1.5 seconds of latency, but was not overly excessive. Personnel using the equipment readily adapted to the delay – similar to learning to deal with satellite phone delay.

One issue that was encountered with the experiment was when we attempted to use the Xybernaut's head-mounted display with the video streaming system. The Windows Explorer window displays with excellent clarity, but the actual video being transmitted is barely distinguishable. The resolution is only adequate enough to make out shapes, but with no real detail at all. Ascertaining the cause of this will be the subject of additional experimentation and analysis. This aspect of the system is not considered to be critical, however, as the primary concern is for the personnel using the Xybernaut system to be able to stream video back to a technician at a shore facility who will have a PC at his disposal and not for the Xybernaut user to be able to receive video, per se. That is not to say that this capability could not be useful if the problem can be successfully addressed, just that it is not a critical factor.

This experiment was deemed successful in that the capability of the Xybernaut system to stream video and voice to a remote location using appropriate hardware (video streaming server, microphone, digital camera) and software (IP protocols, etc.) was proven to be viable. While there are issues of latency and video resolution when receiving video feed on the head-mounted display, these factors are not seen as a significant detriment to the overall effectiveness or viability of the system.

F. STAN 5 EXPERIMENT AT CAMP ROBERTS

The STAN 5 experiment took place at Camp Roberts in Central California at the CIRPAS facility from 20-27FEB2004. This is the same location as the previous Camp Roberts experiment. The focus of this experiment was to evaluate the tactical viability of using Tacticomp tactical PDA computers, wearable computers and mobile robotic and stationary sensors to establish situational awareness on the battlefield.

Central to this experiment was the Situational Awareness Agent developed at the Naval Postgraduate School by Dr. Eugene Bourakov. This software consists of GPS fixed icons representing various assets (sensors, Tacticomps, wearable computers, etc.)

superimposed upon a map of the relevant area. By activating an icon the TOC, or any other asset connected to the network has access to the sensor input, SNMP data and identifying information of the asset represented by the icon. Assets may also text message each other via the SA Agent interface.

The Tacticomp is a hand-held, ruggedized PDA that is carried by combat troops in the field. The unit has an integrated GPS position fixing capability and is easily configured with various sensors and a laser designator capability. Combined with the GPS system, this gives the Tacticomp the ability to enable both Blue and Red force tracking. Tacticomps were utilized in the experiment by Army National Guard personnel who used them to communicate with each other and provide a limited Common Operating Picture (COP) to leadership personnel in the field. Unfortunately, due to software incompatibilities, the Tactical Operations Center (TOC) was unable to establish a link to the Tacticomp platform. This will be discussed in more depth later.

Sensor suites included acoustic, motion detection and seismic event detectors. The sensors were provided and maintained by BAE on site and were linked to the TOC via the wireless 802.11b network. The purpose of the sensors was to establish a detection grid that would alert TOC personnel of attempted infiltrations of the experiment perimeter by enemy forces and help define a tactical COP by establishing locations of various seismic, acoustic and visual anomalies.

Wearable computing consisted of two Xybernaut units configured with heads-up displays, GPS, digital cameras, microphones and the requisite software to allow the cameras and microphones to be used as a mobile sensor suite by the TOC. The main purpose of the wearable computer platform in this experiment was to establish a “self-healing” network capability. The underlying premise of “self-healing” in this manner is that, if a sensor goes down for some reason, a human with a wearable wireless device will be able to enter the network seamlessly and assume the duties of whatever sensor platform has ceased to function.

The initial experiment involved establishing a wireless 802.11b network linking remote sensor suites at a distance of approximately 2 miles with the TOC at CIRPAS. This link was established via K4 directional antennas and an airborne (anchored hot air balloon with a wireless bridge) relay. The wearable computers were initially configured

and a link was established with the network with the wearables on site at CIRPAS. After the wearable connectivity was established and the link with the remote sensor suite was successfully established the wearable computers were moved to the remote sensor location to determine if they could be linked into the remote network. The wearable computers were able to successfully establish a connection with the wireless access point (WAP) at the remote location and were able to establish connectivity via the remote network with the TOC. The realization of a self-healing capability was demonstrated by the wearable users' ability to stream video back to the TOC from this remote location.

The second experiment iteration involved incorporating all of the various assets – Tacticomps, BAE sensor suites and Xybernaut wearable computer systems - in a simulated tactical exercise. This exercise was a live fire evolution that took place on firing range 22 at Camp Roberts. Soldiers from the Army National Guard were outfitted with Tacticomp PDA computers and various sensor suites, both optical and acoustic, were placed in the operational environment.

The TOC was moved onsite at the range and the wireless network was established and verified within approximately 17 minutes after the requisite equipment was on station. The wearable computer links to the network were verified and the experiment began with the combat element engaging in live fire and the TOC recording sensor feedback to movement and acoustic activity created by the discharge of weapons.

The TOC in this scenario represented the Command and Control center that would consist of decision makers being fed data from the various BAE sensors, Tacticomps and wearable computers. The TOC was able to receive sensor reports from the sensor suites, but was not able to connect to the Tacticomp component. This was due to the Tacticomp's inability to interface with the SA Agent software package. The result was that the individual Tacticomp components could "see" each other and communicate, but they could not communicate with the TOC and vice versa.

The wearable computer "self-healing" element was tested concurrently with the live fire exercise. An individual with a wearable computer first established connectivity within the 802.11 shell and then proceeded to move outside the range of the network. Once connectivity was lost, the wearable then moved back within the shell and was able to successfully reestablish a connection with the network. This was a critical factor in

establishing the viability of “self-healing”. The network was stable and robust enough to seamlessly disconnect and reconnect with a mobile node.

The wearable unit was in streaming video mode during the experiment. The TOC was able to see the streaming video up until connection was lost. They were, however, unable to reestablish the video stream even after the network reacquired the wearable. This was due to a glitch in the SA Agent software and will be addressed and corrected. The critical factor was that the network was able to disconnect and then reacquire the mobile node in a seamless fashion as attested to by both Air Magnet and Solar Winds network monitoring software packages in use at the TOC.

The relevance of this experiment to the Naval Aviation Maintenance scenario becomes obvious when seen in the light of the dynamic environment in which shipboard maintenance takes place. There are many opportunities for interference to occur onboard naval vessels and it is absolutely critical that the wireless LAN system onboard the ship be robust enough to handle occasional disconnections and subsequent reacquisition of mobile nodes without complication. This experiment has concluded that this is, indeed, possible. The SNMP monitoring component that is included in the SA Agent software package would be an excellent addition to the working version of the Maintenance Software Package for the Xybernaut wearable computer. This would enable a user to monitor his incoming and outgoing data rates and packet loss ratio and adjust his position relative to a WAP accordingly.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This thesis has addressed the implementation of change within the Navy and potentially the Department of Defense, relative to incorporating wearable computers, augmented reality and collaborative technologies within the framework of naval aviation maintenance and in support of technical assistance. The process and technologies as they exists today have been addressed as has the philosophy behind promoting a new methodology for providing technical assistance to commands who are deployed at sea or abroad.

This thesis has detailed the technologies available to be incorporated into the existing process that will essentially transform it into a “virtual consult” capability enabling technicians to provide valuable assistance to deployed assets without ever having to leave the office. These technologies include Groove Networks collaborative technology, streaming video, augmented reality and CoABS. Wearable computing has been explored as a means of expanding a maintainer’s capabilities by providing access to maintenance databases and digital publications as well as providing the link between himself and the shore-based technician.

Issues involving how the new technologies will be incorporated and how the resulting changes will affect the parties involved have been addressed and recommendations for appropriate training and information dissemination have been made in order that concerns and fears may be allayed and to ensure that leaders respond to resistance appropriately and with understanding of the issues involved.

The practical aspects of cost savings and increased efficiency have been addressed and it has been concluded that although a learning curve will be experienced and an initial cost incurred that the end result will be improved efficiency and reduced cost for the Navy and DOD.

Issues regarding how the morale of both sailors and technicians will be affected were addressed and the conclusion was made that morale is expected to rise with the

appropriate implementation of this change. This is as a direct result of the improved efficiencies, productivity and accuracy of the new system.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

Recommendations for future research include attempting to extend the range of the wireless card on the wearable computer by adding a larger or higher gain antenna. It is also recommended that an attempt to integrate Blue Tooth wireless protocol for the peripherals of the wearable computer be made. This would eliminate the “spaghetti factory” that exists on the present system. While the wires can be contained within specially designed harnesses, it is a potential snagging hazard and a distraction that may be avoided.

Processing speed in the wearable computer is not on a par with present PC or laptop technology. This is primarily due to the requirement to keep battery drain to a minimum, thus a low voltage, less powerful processor is used in the Xybernaut system than most of us are used to having access to on our respective PC’s. This can lead to slow boot times and potential delays in manipulating graphic intensive files. Possible solutions in alternative processors or battery technology should be investigated.

Further experimentation needs to be accomplished onboard an actual Naval vessel in order to determine absolute bandwidth requirements for the system. The system works very well in a shore based environment with broadband access, but the streaming video capability has yet to be tested in a deployed environment. While the system would still be effective utilizing its other functionalities, even if reduced to transmitting digital snapshots, being able to stream video back to the technician is what makes this system really stand out. With the imminent arrival of new broadband satellite constellations such as the Wideband Gap Filler, this should present less of a problem.

As a practical matter, this entire system is heavily reliant upon available bandwidth for its ability to reach back to the shore technician via satellite relay. Currently satellite bandwidth is very limited and in high demand. True 30 fps streaming video requires large amounts of bandwidth and so the system would, necessarily, be limited to some lower rate of transmission until future proposed bandwidth becomes available. The

new Wideband Gap Filler Satellite is capable of data transmission rates in excess of 4.5 Gps. When this new satellite constellation is operational true 30 fps streaming video should become a reality.

Of course, it always seems that as more bandwidth becomes available more and more needs for it arise. For this reason I would recommend researching a way to implement a method of prioritizing data streams transmitted from naval vessels with a preemptive function similar to the POTS system's ability to rank phone calls and give precedence to certain circuits. This would ensure that necessary bandwidth was allocated to priority applications at the expense of less critical ones. An example would be that more bandwidth would be allocated to the Naval Aviation Maintenance system than to a sailor surfing the internet in his off time.

C. CONCLUSIONS

The incorporation of this new technology stands to benefit the Navy and the Department of Defense by reducing expenditures, increasing efficiency and increasing the quality of life for the sailors and technicians who are responsible for maintaining the equipment vital to mission accomplishment. The proper implementation of this technology and proper management of the change involved will result in an increased effectiveness of naval missions and mission accomplishment across the DOD.

The technology, however, is still in its infancy, so to speak. During experimentation it became obvious that there are limitations inherent in the wireless capabilities of the Xybernaut system. These limitations are primarily range, speed of processing, bandwidth available on various platforms and interface issues with the Xybernaut and its peripherals. With the maturation of this technology, these concerns will become less of an issue. It is conceivable that within the next several years that most, if not all of these issues will be addressed and resolved.

It must be concluded that the fusion of the wearable computer system with the several technologies addressed in this thesis stands as a viable and cost effective alternative to the present system of physical technical presence onboard deployed vessels. This new system will reduce cost, increase the efficiency of the maintenance process, reduce aircraft downtime, increase morale, promote readiness and aid in mission accomplishment.

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APPENDIX

Xybernaut Personnel Impact Survey Questionnaire

1) How effective do you feel the current method of NATEC response to maintenance problems on deployed aircraft carriers is regarding:

	Poor			Excellent	
1) Timeliness	**1**	**2**	**3**	**4**	**5**
2) Cost	**1**	**2**	**3**	**4**	**5**
3) Reliability of repairs	**1**	**2**	**3**	**4**	**5**
4) Mission Accomplishment	**1**	**2**	**3**	**4**	**5**

2) How comfortable are you using computers? **1 2 3 4 5**

3) Do you like to try new things? **1 2 3 4 5**

4) How effective do you think a using computer to communicate over the internet is? **1 2 3 4 5**

5) If you could use a computer to ask a tech questions about maintenance and get an answer back in real time, how likely would you be to use it? **1 2 3 4 5**

6) If this same system could enable a tech to "see" what the maintainer sees and walk that maintainer through a tough repair, if necessary, how likely would you be to use it?	**1**	**2**	**3**	**4**	**5**
7) How much of an impact do you think a system like this would have on the Navy?	**1**	**2**	**3**	**4**	**5**
8) How do you think this would affect your morale or that of your coworkers?	**1**	**2**	**3**	**4**	**5**

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